

[0023] The current that is supplied to the conductors, can be primary and secondary characteristics of the corresponding pixels, and combinations thereof. The characteristics can include gray-scale intensity, color, and gradients. In addition, depth values can be determined for the image, in which case the surface of the layer 100 essentially becomes a contour map of the image. The conductors can also be pulsed, depending on other image qualities or associated information known to the application. For example, the surface can be made to vibrate or pulse at different frequencies in different locations.

[0024] The device can convey three-dimensional spatial information, as well as temporal information. That is, the detectable surface features can move. In this way, the device can also be used as a navigation aid. For example, the contour is a 'map' of a local area in an immediate vicinity of the user, indicating perhaps, walls, doors, curbs, and other potential obstructions. The user's current location is indicated with vibration. The user can now safely navigate in a particular direction, or be guided to do so.

[0025] FIG. 4 shows an alternative embodiment, where two layers are used. In this embodiment the user can grasp the device like a sandwich, and receive different tactile input from each layer.

[0026] Electro-active polymers are well known, see Hamlem et al., "Electrolytically Activated Contractile Polymers," Nature, Vol. 206, p. 1149-1150, 1965. Because of their many desirable properties, most applications, up to now, have been in the medical field, where the polymers are used to construct artificial muscle, organs, lenses, and the like. A good review is given by Brock, D L et al., "Review of Artificial Muscle Based on Contractile Polymers," MIT AI Memo No. 1330, November 1991. Industrial applications are also described by Shahinpoor et al., "Ionic polymer metal composites: IV. Industrial and medical application, Smart Materials and Structures, Volume 14, Issue 1, pp. 197-214, 2005.

[0027] A tunable diffraction rating is described by Aschwanden et al. "Polymeric, electrically tunable diffraction grating based on artificial muscles," Optics Letters, Vol. 31, Issue 17, pp. 2610-2612, September 2006. A vertical membrane is made of artificial muscle, and has carbon electrodes attached to its sides. The membrane has one side molded into a diffraction grating and coated with gold to increase reflectivity. As the applied voltage varies, so does the periodicity of the diffraction grating, changing the angle of the diffracted light.

[0028] However, to the best of our knowledge, electro-active polymers have not been used in graphic application, where individual areas of the polymer are activated to convey image data as texture on a surface of the polymer.

[0029] Although the invention has been described by way of examples of preferred embodiments, it is to be understood that various other adaptations and modifications may be made within the spirit and scope of the invention. Therefore, it is the object of the appended claims to cover all such variations and modifications as come within the true spirit and scope of the invention.

I claim:

1. A tactile output device, comprising:  
an electro-active polymer layer;  
first and second sets of conductors arranged proximate to the layer, in which the first and second sets of conductors are approximately at right angles to each other and coplanar, and the conductors in each set are spaced apart and parallel to each other to form an array of points where the conductors intersect; and  
means for individually selecting the conductors to convey current to expand and contract the electro-active polymer in vicinities of the points.
2. The device of claim 1, in which the array of points correspond to a pixel array in an image.
3. The device of claim 1, in which the conductors are embedded in the layer.
4. The device of claim 1, in which the conductors are cylindrical in cross section.
5. The device of claim 1, in which the conductors are rectangular in cross section.
6. The device of claim 1, in which the conductors are deformable.
7. The device of claim 1, in which the array of points is regular.
8. The device of claim 1, in which the array of points is irregular.
9. The device of claim 1, in which an amount of expansion and contraction is controlled by an amount of the current.
10. The device of claim 1, in which the expansion and contraction forms a three-dimensional texture.
11. The device of claim 1, in which the conductors are coupled to a frame buffer.
12. The device of claim 1, in which an amount of expansion and contraction corresponds to gray-scale intensities in an image.
13. The device of claim 1, in which an amount of expansion and contraction correspond to a contour map of an image.
14. The device of claim 1, in which the conductors are pulsed at different frequencies.
15. A method for generating a three-dimensional image, comprising:  
arranging first and second sets of conductors proximate to an electro-active polymer layer to form an array of points where the conductors intersect; and  
selecting individually the conductors to convey current to expand and contract the electro-active polymer in vicinities of the points.
16. The method of claim 15, in which the array of points correspond to a pixel array in an image.
17. The method of claim 15, in which the expansion and contraction forms a three-dimensional texture on the layer.
18. The method of claim 15, in which the conductors are coupled to a frame buffer.
19. The method of claim 15, in which an amount of expansion and contraction corresponds to gray-scale intensities in an image.
20. The method of claim 15, in which the conductors are pulsed at different frequencies.

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